coloration. The same result was obtained when a slip was exposed in the same manner between tightly sealed plates of glass. But when the glass was cracked, to allow the access of atmospheric oxygen in the presence of sunlight, the paper slip became perceptibly colored in a few hours. Thus is suggested a very interesting explanation of the well-known importance of the access of an abundance of bright sunshine, for pure air and good health within our homes. All these fragmentary facts show what a fascinating field for study and investigation lies within our easy reach; and when we add to all this the peculiar importance which attaches to this subject in our own State, our attention is awakened with redoubled interest. These carefully recorded observations in progress for the two years past have established beyond a doubt, the existence of a liberal quantity of ozone in Kansas atmosphere. The universally healthful character of the climate of the State, is so widely known a fact as to need no comment here. And in addition to our almost absolute freedom from epidemic diseases of every character, our State is just now attracting very general attention as a desirable resort for consumptive patients. Sufferers unable to endure the rare atmosphere of the higher regions of Colorado, now frequently find returning health by a protracted residence in Kansas. Has the ozone of our atmosphere any connection with this fact ? is an inquiry not infrequently addressed me by interested physicians from the East—to whom a satisfactory answer can be given only after long study and extended observation. In view of all the interesting features of this attractive theme, I can conceive of no more promising a subject of study than this of the offices of the ozone of our atmosphere in health and disease. Such an investigation may not, to be sure, either lighten our taxes or increase the value of our farm products. But it will be the means of revealing to us more fully an accurate knowledge of the wonderful resources with which nature has endowed us as a State; upon which, after all, rests the foundation stone of our material prosperity.

ON SOUND TRANSMISSION BY ELECTRICITY.

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Two years ago a Boston teacher of vocal culture astonished the world by exhibiting at Philadelphia an instrument by which a person, talking, singing or making any sound at one extremity of an electric circuit, might have the same words and tones faithfully reproduced at the other extremity.

At that time few people knew that this subtle agent, electricity, could be employed in the transmission of sound, though this thing had been done many years previously.

In 1837, Prof. Chas. Grafton Page, for many years an Examiner in the Patent Office, utilizing Prof. Henry's discoveries, succeeded in producing what he termed "galvanic music." This phenomenon at once attracted the attention of the scientific men, and, among others, the French electrician, De la Rive, investigated the subject with great care in 1843. Nothing came of these researches, except to add another laboratory experiment illustrating the physical principles of electricity.

In all these cases the sound transmitted was first produced by the

vibrating spring of an electric coil which opened and closed an electric circuit; and the same tone was reproduced by an electro-magnet through which the interrupted current passed, and whose vibrations corresponded with those of the spring of the induction coil.

There was, following this, more or less crude speculation on the possibilities of transmission of sound by electricity, but nothing better than De la Rive's experiments is recorded till 1861. At that time Reiss, teacher of a school at Friedrichsdorf, near Homberg, entered the field of investigation with the true German spirit. His first telephone was made with a beer barrel, the bung of which was pierced with a conical hole, and over the smaller end the skin of a German sausage was stretched. Another tubular opening into the barrel allowed this membrane to be put into vibration by tones of the voice. These vibrations, by suitable mechanism, opened and closed an electric circuit, and the interrupted current passed through an electro-magnet properly mounted on a box for strengthening the sound.

The German pedagogue still flourishes, and has made many improvements in his original telephone—some of quite recent date.

A writer in the Polytechnisches Notizblatt, in 1863, says, that not only tones, but words, could be communicated by Reiss' telephone, if such as heard frequently; and in 1865, Yeates, an instrument maker of Dublin, introduced a modification of Reiss' instruments that was said to transmit words well, by members of the Dublin Philosophical Society. Reiss named his invention a telephone, a name that had then been in use many years, and was applicable to all instruments for transmitting sound to a distance. Reiss suggested that this kind of sound transmission might be the basis of improvements in telegraphy, but no practical applications were made, and telephones were merely philosophical toys until Bell's work culminated in 1876.

Till that date our best text books, if allusion was made to it at all, dispatched the subject of electrical transmission of sounds in a paragraph. Since then, the progress of the science has been simply wonderful, for we may surely call telephony a science bringing forth several volumes in two years, and being the subject of articles innumerable in all classes of journals, and the topic of inquiry and curiosity everywhere. I have no time to pursue my theme historically, any further, nor do I wish to enter on the disputed question of priority.

A discussion of principles and applications is more worthy the attention of the Academy.

We may divide electric telephones into three classes: 1st. Those already described, where the vibrations of a reed, or membrane, cause interruptions of an electric circuit, thus sending intermittent currents to a distant station. These currents have the same frequency as the pulsations of the sound-wave that caused the interruptions, and will produce in the electro-magnet pulsations of like frequency. We thus get a tone of the same pitch as the original note which is sung by the voice or emitted by the vibrating reed. The quality of the tone—its timbre, will depend on the kind of mounting given to the electro-magnet. The most elaborate telephone of this class, yet constructed, is that made by Prof. Gray, of Chicago. For the original tones he used reeds of different pitch, vibrated by electric influence which was controlled by keys like those of a piano. At the receiving end he had an ingenious and complicated apparatus for reinforcing the sound. It was Prof. Gray who gained such wide celibrity by his telephonic concerts, in the first of which, music in Chicago was reproduced in Milwaukee, greatly to the surprise and delight of a large audience.

Prof. Gray, as electrician to a telegraph company, naturally sought to utilize the principles of his musical telephone in multiplex telegraphy, and has been measurably successful, though the time does not seem ripe yet for its universal adoption. Aside from its novelty, the music from this sort of telephone has no special charm. It is apt to sound weird and doleful, and reminds one of hand organs, such as are ground by old beggar-women, to attract notice and sympathy, sitting with their starved children beside a gutter. As a musical instrument it is not a success, as Artemus would have said.

Telephones of the second class, of which Bell's instruments were the precursors and type, soon gained popular attention, not only by their interest but by their practical applications also. Bell's researches were begun and carried forward in the true spirit of the philosopher, and though the goal reached was not at first aimed at, he exhibited true genius in seizing the clue offered, and following it out so faithfully. Following in the footsteps of a father somewhat famous as the author of "Visible Speech," Bell was seeking some way to make the sound-wave give a permanent, visible and legible record of itself. He found the manometric capsule of Konig, and the phomantograph of Leon Scott, unsuited to his purpose, and sought to improve the latter by making it after the model of the human ear. A friend suggested the use of the ear itself, and the success of their experiments with this novel apparatus gave the clue that Bell needed. If, thought he, a membrane like the tympanum of the ear can move a series of bones, relatively of large size, why will not a larger membrane move a magnet that will vary the intensity of the electric current in waves corresponding to the sound waves? He had before sought in vain to reach a similar result by the means of sympathetic vibrations, but his new effort with the vibrating plate was crowned with triumphant success.

I have indulged in this sketch of the genesis of the vibrating plate since it is to be regarded as the fundamental idea of the second class of telephones, and one of the most suggestive and fruitful discoveries of the age. Three forms of instruments were exhibited at the Centennial, Philadelphia. The principle in each was the same, and in construction there was a battery sending a continuous current between the receiving and sending stations. At each of these places it passed through coils of fine insulated wire, having as a core a piece of soft iron. This of course became a magnet, and directly in front of it, distant say one-thirty-second of an inch, was fixed a thin plate of iron. A suitable mouth piece before the plate converged the sound upon it and gave the vibrations. It must be remembered that the iron plate is in the magnetic field and has become a magnet. Its vibration, therefore, according to well-known electrical principles, caused electric pulsations to pass through the coil of wire, the intensity and direction of the currents being proportional to the velocity and direction of the moving plate. A vibrating plate, according to well-known acoustic laws, has property of dividing into nodes and ventres so that it can harmonize with any sound-wave, however complex. Thus it results that the plate copies the sound-wave and the electric pulsations copy the plate. Now these pulsations passing through the helix at the receiving station, change the magnetic state of its iron core, and consequently the attractive force of the latter on the plate in front, just in proportion to the frequency, intensity and direction of those pulsations. A vibration thereupon ensues which copies in all its minute detail the original vibration of the first plate and sound-wave. This is transmitted to the air and thence to the ear. Thus we have a sound-wave which by instrumentality of a magnetic plate is

copied by an electric wave, and this in turn is retranslated into a similar sound-wave. The original sound dies like any other sound, but its photograph, as it were, has been copied in a more subtile medium than air, and so it lives and moves and is born again.

In a few months after its exhibition at Philadelphia, this invention had received such development at the hands of Mr. Bell that subsequent progress has been slow, and the most recent telephones show little improvement over those made a year ago. Bell found that the size and thickness of the vibrating plate, likewise the strength of the battery, could be altered in pretty wide limits without materially changing the loudness of the tones at the receiving station. In his experiments he varied the plate from one inch to two feet in diameter, and from one-sixty-fourth to three- eighths of an inch thick. Between these limits he found the articulation perfect, though if too small or too thin the tones had a nasal character, while it sounded like talking into a barrel if the plates were too thick or too broad. Likewise in the battery, he left off one cell after another, until finally all were removed, and still he could talk through the instrument. This was due to residual magnetism as he afterward found, but it led to the abandonment of batteries and the substitution of permanent magnets for the iron cores. This is the form in which the Bell telephone is now used, with no battery and no continuous current, being purely magneto-electric in its principle of action. It must be evident, prima facie, that such a telephone can only talk in low tones. Only a small part of the original sound impulse can be changed into electricity, and this in turn can deliver but a small fraction of its force to the ear of the listener. It has been, therefore, from the first, a desideratum to increase the loudness of telephone messages. In quality they were all that could be desired, but the still small voice was hard to be distinguished by unpracticed ears. Hence the long continued experiments of Prof. Bell alluded to. It was found that if an increase was attempted by shouting the original message, the quality of that delivered was much impaired. The sounds, though louder, became indistinct and unintelligible. This was owing to another principle of electro-magnetism, which came into operation in such a case. The electric intensity of telephonic currents depends not only on motion of magnet being directly proportional to velocity of the vibrating plate, but they are inversely as square of distance. Now when the motion of the plate is very small, perhaps chiefly molecular, when moderate tones are used, the variation of distance is so small as to give no appreciable difference on this account; but when the tones are loud, the air-waves give the plate such motion that the law of inverse squares comes in, and the electric pulsation is no longer a faithful copy of the sound-wave.

All attempts, then, to increase loudness by larger battery power, varying the dimensions of the plate, or by increasing the volume of tone at the transmitting station, fail, in great degree, to reach the end sought. Many inventors have tried their skill at this problem without much success. The question then arises, is there not some other way, save by motion of a magnet, of modifying the electric current so that it shall faithfully represent sound-waves?

This leads us to the third class of electric telephones, of which Mr. Edison's inventions furnish the best examples. The genius of Menlo Park, whose fame is world-wide now, owes his reputation most of all to the phonograph, an invention suggested, doubtless, by Bell's telephone, in an attempt to improve the latter. It is not my purpose to discuss that at all, though it is not a little curious that Edison, seeking to improve on Bell's discovery,

should incidentally solve Bell's original problem, and, not only that, should also hit on a new line of telephone improvement which vastly increases the possibilities of this invention. All workers with current electricity know how important it is to secure firm metallic contacts in conductors. Here is an invention whose success depends on a loose contact. Edison's merit and success in telephones probably lies chiefly in the invention of the carbon button, which, likewise, is the foundation of the tasimeter and a dozen other novel instruments. It, therefore, merits a special description, easy to give, for it consists simply of compressed lamp-wick arising from incomplete combustion of coal oil. It is pressed, with a force of 1,000 pounds to the square inch, into the form of a little disc, one-half of an inch in diameter, and one-sixteenth of an inch thick, the breadth and thickness of an old-fashioned wafer for sealing letters. The carbon button is placed between two metallic discs, which are, in turn, joined to wires forming opposite poles of an electric circuit. The electric current, therefore, passes through the carbon. The discs which form the sides of the carbon are so arranged as to be exposed to the influence of sound-waves. These, by their condensations and rarefactions, increase or diminish the contacts of the disc with the carbon, and thus vary the flow of the electric current. This variation is found to be in such exact proportion to these small pressures that an ordinary Bell telephone reports with fidelity a message transmitted by Edison's instrument.

In applying the carbon button to the tasimeter, the heat rays are made to pass through a slit and fall upon a little bar of hard rubber. This is very sensitive to heat, and by its expansion presses on the carbon button, thus increasing the electric current, as witnessed by a delicate galvanometer. Again, the carbon button is used for a new kind of barometer, and also for a hypsometer, to measure the atmospheric moisture. Hughes' microphone employs the same principle of loose contact as the carbon button. It may have a great variety of forms, one of which consists merely of three iron nails—the two being connected directly with the poles of a battery, and the third nail being loosely laid upon these. Another way is: Make a box with tin plates passing into the interior on opposite sides, which are thus connected with the poles of a battery. The box is now filled with gas cinders, and becomes a microphone. Three or four of these hung on the walls of a room, like picture frames, were sufficient to transmit conversation going on in the room, thus realizing not only the idea that walls have ears, but mouths, too.

Time does not allow even an allusion to the many modifications that have been made in the forms of the last two classes of telephones. In spite of all that has been done, distinct articulation by telephones can be given, as yet, only in comparatively low and feeble tones, and we yet wait for Edison, or some other genius, to complete the instrument which will deliver popular harangues or concerts, and report speeches. Aside from any direct practical applications, there is a wide field of interest in the purely scientific aspect of telephones. Through them we see the inner workings of molecular forces from a new and most interesting standpoint.

We discover new evidence of the marvelous delicacy of the ear, and, conjoined with the kindred invention, the phonograph, we are possessed, for the first time, of the means for making a complete scientific analysis of speech, and may hope to make record of this fugitive aerial movement, which has hitherto been lost like the track of a vessel through the sea. Finally, the telephone teaches the wonderful potency of little things, and that many forces we count as lost go on and on, and return, perhaps, at last, to their origin, after cycles of change.